Understanding Information Propagation using Bio Inspired Computing

A brief outline of the proposed research to be carried out in pursuance
for the award of the degree of

Doctor of Philosophy
in
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Area of Research
Bio Inspired Computing

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1.0 Introduction

With the advent of internet and highly fault tolerant communication media enabled us to share information across boundaries. As a result there has been an explosion of data travelling across the network in one or the other form. The spectacular growth of social media and online information sharing social networking systems sites presented a big challenge in front of the research community to identify, analyze and characterize the information propagation speed and patterns in these social networking systems. Social networks can be viewed as a structure which enables the dissemination of information among the users. This dissemination constitutes the flow of information among individuals through social interactions. The problem of maximizing interactions and increasing the spread of information is known as influence maximization. The analysis of the dynamics of such interactions is a challenging problem in the field of social networks.

The study of influence maximization is beneficial to cater the growing needs of organizations for developing competitive strategies for their product promotions, for behavioral analysis, early detection of fake news and so on. These applications aroused a need for detailed analysis of this problem.

This research proposal explores different models of Information Propagation and Influence Maximization in Social Networks and the applicability of Bio Inspired Computing in Social Networks and proposes to study on some of the challenging problems in propagation of information using Bio Inspired Algorithms. For Example, to analyze and determine the most prosperous seed for influence maximization, a twitter data sets can be probed and explored along the influence diffusion measures i.e. retweets, indegree and mentions [Cha et al.,2010]. And then the impact of human behaviors and personality traits (i.e. openness, conscientiousness, extraversion, agreeableness and neuroticism) on the information propagation could be studied [Qiang et al.,2013]which will help in characterization of nodes along these parameters and identifying the solution of influence maximization which could be optimized using Swarm intelligent algorithms.

2.0 Review of Social networks and its applications

With the invention internet and technological advancement in telecommunication and pervasive computing, a tremendous multiplication in information generation is found in social network [Sreedhar,2016, Hassan et al.,2016].

A social network is defined as a network of interactions or relationships, where the nodes consist of actors, and the edges consist of the relationships or interactions between these actors. This kind of complex social structure could be studied with respect to the structural characteristics of the social network, user group and its behavior, and information diffusion and analysis in social network [Chen et al.,2013]. The outburst of rich data or information that gets propagated across the social networks can be leveraged for analysis and thus in turn have provided unprecedented opportunities for study of information dissemination and data analytics in context of social networks.

The various business applications areas of social media are online marketing, tourism, media, retailing & manufacturing, education, healthcare, political communication, brand communication, industry and financial sectors. All the prevailing areas of business are evolved with the introduction of social media [Grover et al.,2018, Peng et al.,2018, Stieglitz et al.,2014, Manfred et al.,2012, Grover et al.,2017, Hennig et al.,2010].

The introduction of the social (and monetary) rewards for generating 'viral' multimedia broadcasts and viral marketing caused the spread of rumors, stories, interest, trust, referrals, behavioral targeting, feed ranking, "friends" recommendation and social search rapidly aroused a big challenge that require a detailed investigation of the propagation of information across social networks [Chen et al.,2013].

In each one of these implementation areas, certain set of influential users are selected for promotion and propagation yielding a maximum influence [Peng et al.,2018]

The wide acceptability of these applications aroused various challenges which are to be addressed are:

- Detecting Special Individuals- Individuals are identified with certain behavioral characteristics that may be profitable to certain organization. [Soryani et al.,2011]
- Monitoring and analyzing user activities- User's behavior are to be analyzed to identify some pattern in their community or group that enable easy dissemination of information.[Anna et al.,2010, Kartarzyna et al., 2009, Soryani et al.,2011]
- Community Detection- identifying the set of users that may be fruitful for execution of some sort of task with minimum communication cost. [Soryani et al.,2011, Theodoros et al.,2009]
- Influence maximization: Companies are in need to identify the seeds by which the spread of information can be maximized. [Chen et al.,2009, Soryani et al.,2011]
- Recommendation and suggestions- this information act as an aid to enhance the search results of a user [Soryani et al.,2011]

Among all these problem areas information propagation is the underlying methodology followed in all applications. It was also investigated that information propagation varies as the social network structure changes [Li et al.,2016, Hema et al.,2012]. So to analyze the data traffic and to discretize the communication links by identifying the latent links from generalized links, information propagation model is to be explored. Considering the broader aspect of the information propagation analysis, it could be visualized in four domains. They are: Information Propagation in Social Networks, Wireless Networks, multimedia propagation, security [Selva et al.,2017].

Some of the most challenging problems in information propagation across social networks include maximizing influence [Kempe et al.,2003], social contagion [Ugander et al.,2012] and bursty behavior of content rich message [Chenyi et al.,2013].

Influence maximization [Kempe et al.,2003] refers to the selection of certain number of seed users that could influence maximum number of other users in a social network. Social contagion [Ugander et al.,2012, Chenyi et al.,2013] is considered as the process of diffusion of information such as political opinions in social networks. Both of these problem areas focuses on the link structure of a social network to influence more users, detect communities and spread information with minimum communication cost [Chenyi et al.,2013]. Characterizing the user behavior is another interesting area

of research in Information propagation and Social networks. Developing versatile influence model encompassing competitive influence and influence diffusion based on sentiments and emotions can bring better insights in understand human behaviors and emotions of the social agents [Christakis et al.,2007, Zhang et al.,2012, O'Donovan et al.,2013].

The Influence Maximization is an NP-hard combinatorial optimization problem [Lappas et al.,2010]. Therefore, in order to solve this problem, researchers have explored to adopt Bio Inspired Computing Algorithms such as evolutionary and swarm intelligent algorithms which have the capability of handling dynamic environment problems efficiently.

The reminder of this research proposal is as follows. Section 3, elaborates the role of information propagation in social networks with different models and discusses influence maximization as major research area with challenges, Section 4 focuses on the behavioral aspects of users responsible for influence maximization, Section 5 elaborates the research methodology for adopting a bio-inspired algorithms for Information propagation and influence maximization and section 6 defines the various research objectives.

3.0 Information Propagation in Social Networks:

In a social network, information in stream keeps updating itself during propagation. The behavior change could be predicted by analyzing the cumulative modifications during the propagation process however, information dissemination depends not only on connections among nodes but also on their strategies [Qiu et al.,2014].

Information propagation can be studied using various models such as epidemics, influence, independent cascade, linear threshold and game theory models. Epidemics models are divided into three basic mathematical models; they are SI (Suceptible Infected) model, SIS (Suceptible Infected Suceptible) model and SIR (Suceptible Infected Removed) model [Li et al.,2017]. Each one of the models has discussed the nature of nodes defining their role in maximizing propagation. Influence models discusses individual influence, community influence, and influence maximization models. Different information propagation models are described in the Figure 3.1.

The individual influence focuses on mining opinion leaders who will act as a bridge for information diffusion. Community detection forms the base for community influence research. The problem of community detection is closely related to the problem of finding structurally related groups in the network. It includes links-based, content or attributes-based and sentiment-based methods. And lastly the influence maximization model which encompasses the above two models (i.e. community and individual) but its major concern is to find seed nodes for maximizing influence. [Li et al.,2017]].

Apart from these models, two most widely used propagation models are the Linear Threshold Model (LTM), which assumes that a node will only activate after the activation of certain number of neighbors, and the Independent Cascade Model (ICM), which assumes that when a node activates, each of its neighbors has a probability of activating, resulting in a cascades of activation [Alireza et al.,2013].

Each of these models tries to formulate the nature and social behavior of nodes involved in propagation. This nature of a node can be active or inactive depending on its activity weather it adopts or discards the information [Wang et al., 2015]. These active nodes can further be identified in two perspectives i.e. they could be followers who just forwards the message on network or a modifier who modifies the received message and then forward it. Above all the main purpose of these models is to maximize the spread of information.

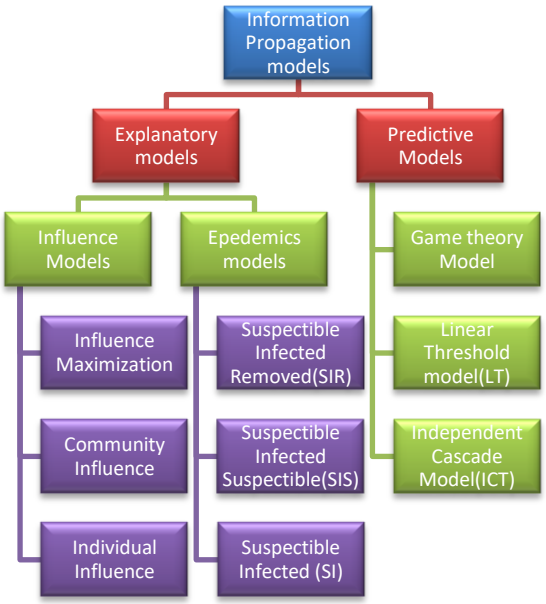

Figure 3.1: Information propagation models [Li et al.,2017]

The influence maximization provides new options for further research analysis to determine its impact on society:

- Emotion analysis: For analysis a technique could be used for propagating information related to sentiments on a knowledge graph constructed using existing lexical resources [Dragoni et al.,2015].
- Financial Analysis: For financial analysis data from financial news could be extracted that bears various economics-related technicalities [Komura et al.,2016].
- Rumor Analysis: For rumor analysis, an analytical technique could be used to make differentiation between positive and negative forms of information in social networks [Wen et al.,2015].

4.0 Information Propagation affected by Emotional Intelligence of participating Users:

The information propagation in online social networks follows a rhythm and activity pattern of human users [Ashton et al.,2007, Karsai et al.,2012]. This human activity pattern could be heterogeneous and bursty when considering the time interval as a parameter of propagation described by a power law interevent time distribution [Vazquez et al.,2005, Zhao et al.,2011, Hong et al.,2009, Wu et al.,2010]. This impact of human activity pattern can also be studied based on its nature as a follower or modifier depends on their personal intelligence. This diffusion analysis can be arranged according to the social behavior of an individual. A social behavior of a person is reflected through their emotional intelligence encompassed around Big Five personality traits - Extraversion, Agreeableness, Conscientiousness, Neuroticism, and Openness to Experience [Dehghanan et al.,2014]. The Extraversion or Surgency includes behavior like talkative, assertive, and energetic, Agreeableness includes good natured, cooperative, and trustful, Conscientiousness holds orderly, responsible and dependable, Neuroticism versus emotional stability constitutes features like calmness, not neurotic and not easily upset, Openness or Intellect includes intellectual, imaginative and independent minded. As these components seem to be tied to person's genetics rather than to environment impacts, they are stable in nature. These parameters will determine personality of a person while analyzing the social structure of any information. A HEXACO personality model [Smith et al.,2015] can be used to portray the nature of individuals propagating information in social network and identifying the prosperous

seed for influence maximization. The HEXACO model can be defined as: Honesty-Humility, Emotionality, Extraversion, Agreeableness, Conscientiousness, and Openness to Experience. Honesty-Humility will be in a person who is modest, fair and sincere. Emotionality will be in a person who exhibits anxiety, fearfulness, and dependence. The definition of extraversion describes a person with liveliness, expressiveness and social boldness. Agreeableness can be defined in terms of patience, forgiveness, flexibility, and gentleness. The conscientiousness trait is generally defined as those who are diligent, organized, and prudent. An openness to experience trait is defined as one who is creative and inquisitive [Ashton et al.,2007].

In this research study, we explore to develop models to maximize the influence and to early detection of false news by identifying and selecting prosperous seeds based on emotional intelligence.

5.0 Research Methodology

This research will work in two phases. In the first phase objective is to identify various prosperous seeds and performing social media analytics over them and in second phase attempt should be made for identifying and implementing bio inspired algorithm for influence maximization.

- **Social Media Analytics:**

  In the process of information propagation across social media, every node gets infected by the underlying processes or the communication factors, resulting in information dissemination. This information encompasses plain text to RSS feeds, blogs, wikis and news resulting in an unstructured text accessible through the web. Information could also be extracted from certain group of nodes constituting seeds from highly diversified environments like Universities / Educational Institutions in particular DEI University. The presence of complex data sets provides a challenge to extract a dynamic pattern from a given set of multi-heuristic data. To make use of this rich data, it has to be analyzed which could be further used for identifying and studying the problem of influence maximization. To cater this challenge social media analytics are performed with respect to four broad categories [Grover et al.,2018]. They are- descriptive analytics, content analysis, network analysis, and geospatial analysis. The descriptive analysis comprises of basic

descriptive statistics and content analysis refers to the extraction of the semantic content from text data. Networks analysis help in detection of communities and groups of users on the basis of their opinions and thoughts expressed on social networks and Geospatial analysis, integrates the two broad categories for analyzing data: location specific analysis, and time-trend specific analysis. The time-trend analysis enables the study of variance in the evolution of topics and trends over the period of time [Batrinca et al.,2014]. After the detailed investigation of the contents and information, analysis could be performed in determining the solutions to the influence maximization problem by considering the various personality traits of most influential seeds present in the social network. Then optimal solution is to be identified by applying bio-inspired algorithms.

- **Application of Bio-inspired Algorithms in Information Propagation:**

As more and more people are connecting to social media, there has been an exponential increase in the generation of data. This explosion of data is making it more and more challenging to extract meaningful information and gather knowledge by using standard algorithms, due to the increasing complexity of analysis [Arpan et al.,2016]. To address the above challenge, along with many other techniques, researchers have also been developing algorithms inspired by the nature to find solutions to complex problems. This area is generally referred as Nature Inspired Computing.

Nature inspired computing is one of the main branches of natural computing techniques and an emerging computational paradigm for solving large scale complex and dynamic real world problems. Nature inspired computing builds on the principles of emergence, self-organization and complex systems [Yoshida et al.,2010].

Some of the well known areas of Nature Inspired Computing are:

- Algorithms Inspired by Evolutionary Theory - Evolutionary algorithms
- Algorithms Inspired by behavior of groups of agents - Swarm intelligence algorithms
- Algorithms Inspired by natural immune system - Artificial immune systems
- Algorithms Inspired by human interactions and beliefs in the society - Social and Cultural algorithms

- Algorithms Inspired by Quantum Phenomenon- Quantum Inspired Algorithms

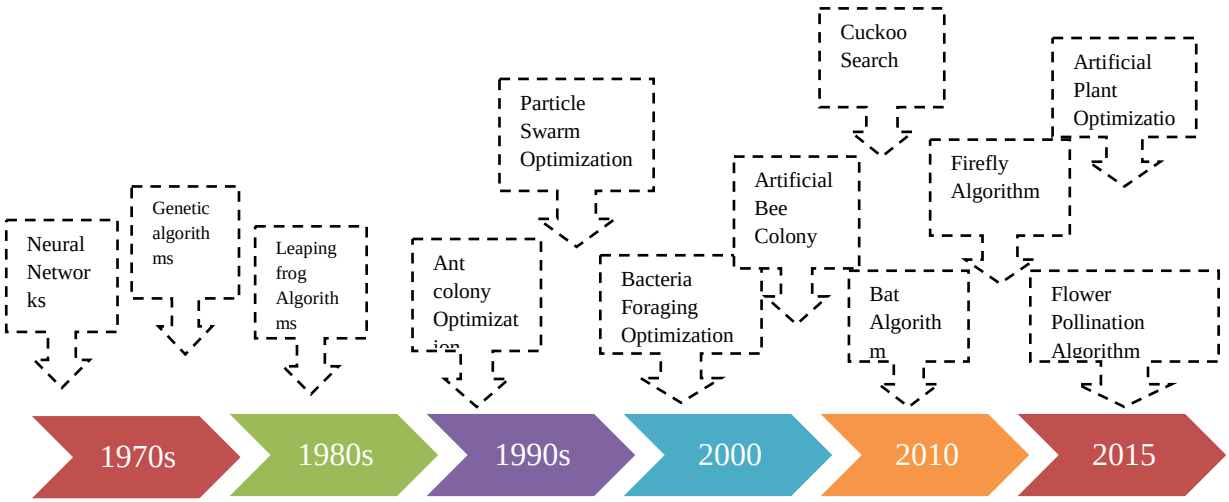

Figure 5.1 Timeline of evolution of Bio inspired Algorithms

Among the Nature Inspired Algorithms, the algorithms that are inspired by the principles of natural biological evolution and distributed collective behavior of social colonies have shown excellence in dealing with complex optimization problems are considered as Bio Inspired Computing. Some of the most successful categories of Bio Inspired Algorithms are Evolutionary Algorithms, Swarm Intelligent Algorithms, Artificial Immune Systems and Social, Cultural and Social Evolution algorithms.

Evolutionary algorithms (EAs) are as search based stochastic optimization algorithms mainly inspired by the process of biological evolution. Some of the EA variants include, Genetic Algorithms [Goldberg et al.,1989, Fogel et al.,2006], Evolutionary Strategies [Beyer et al.,2002], Genetic Programming [Banzhaf et al.,1998, Koza et al.,1999, Poli et al.,2008, Korns et al.,2010] and Evolutionary Programming [Fogel et al.,1966].

Swarm intelligence can be defined as “a property of a system of unintelligent agents of limited individual capabilities exhibiting collective intelligent behaviour” [White et al.,1998]. A swarm can be considered to be a loosely structured collection of interacting agents [Kennedy et al.,2001]. Some of the most successful swarm intelligent algorithms include Artificial Bee Colony

Optimization [Karaboga et al.,2007], Particle Swarm Optimization [Kennedy et al.,2001], Ant Colony Optimization [Dorigo et al.,1997, Hu et al.,2008] and Artificial Immune System [Kennedy et al.,2001], bee optimization algorithm [Zhang et al.,2010], individual bird based algorithms based on doves [Su et al.,2009] and eagles [Yang et al.,2010]; individual insect based algorithms like fruit fly [Pan et al.,2012], wasp [Theraulaz et al.,1991], and glow-worm [Krishnanand et al.,2005]; individual animal based algorithms like monkey [Mucherino et al.,2007], shark [Hersovici et al.,1998] wolf [Liu et al., 2011] and lion [Yazdani et al.,2015].

Another variant of Swarm intelligent algorithms include algorithms inspired by human interactions and beliefs. Some of the most popular algorithms in this area are Cultural Algorithm [Reynolds et al.,1994, Robert et al.,2008], Society and Civilization Algorithm [Ray et al.,2003] and Social Evolution Algorithm [Pavithr, et.al, 2016].

According to *No Free Lunch Theorem,* for any algorithm, any elevated performance over one class of problems is exactly paid for in performance over another class [Crina et al.,2007]. To take the benefit of one or more algorithms to solve a complex problem research have combined the features of two or more different algorithms to form different hybrid algorithms.

Even though, there are huge set of applications where Bio Inspired Computing applications are applied, their potential of these algorithms have not been fully explored in Information Propagation in social media. Based on the research surveys, we can observe that, basic models of few nature inspired algorithms such as Genetic Algorithm [Arpan et al.,2016], Particle swarm Optimization , Bat Algorithm , Artificial Bee Colony Optimization Algorithm and Grey Wolves Algorithm have been applied in this domain. A lot of successful hybrid variations of these algorithms along with Social and Cultural Algorithms, Quantum Inspired Algorithms have not been applied to study the problems related to Information Propagation in social media.

To address this gap in the literature, this research study consider to apply some of the Evolutionary and Swarm intelligent models and their hybridizations to address the above identified problems in the areas of Social media information propagation such as Influence Maximization, Community detection and behavior analysis of social agents.

6.0 Research Objectives:

Based on the motivation outlined in the previous sections, the objectives of this research are identified as follows:

- To study the behavioral and personality aspects of users in information propagation in social networks
- To study dynamics of communities that facilitates the information propagation using bio inspired computing
- To identify the drivers for breaking news/ latest trends/buzz in social media using Bio Inspired algorithms

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